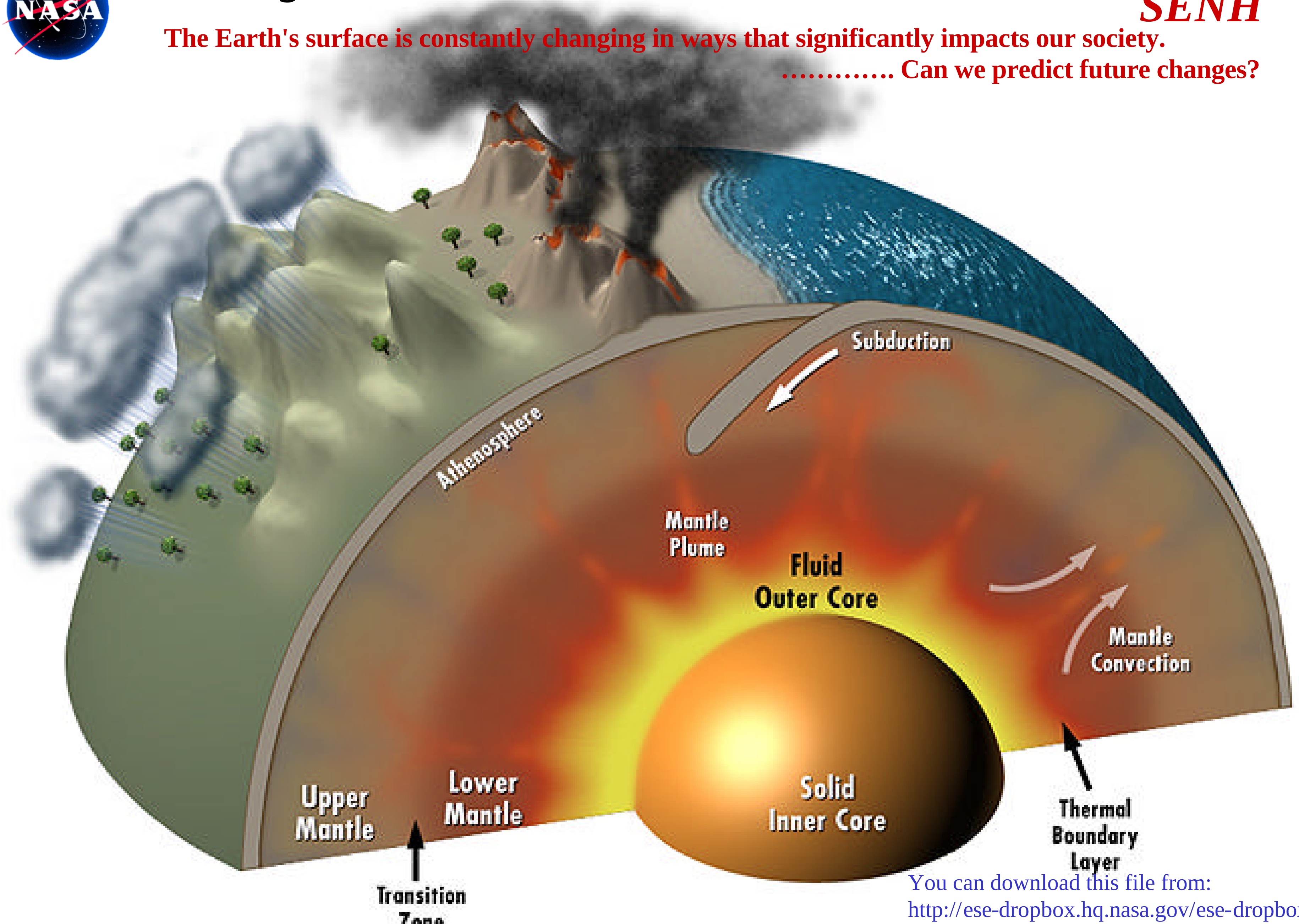
Living on a Restless Planet

SENH

The Earth's surface is constantly changing in ways that significantly impacts our society.

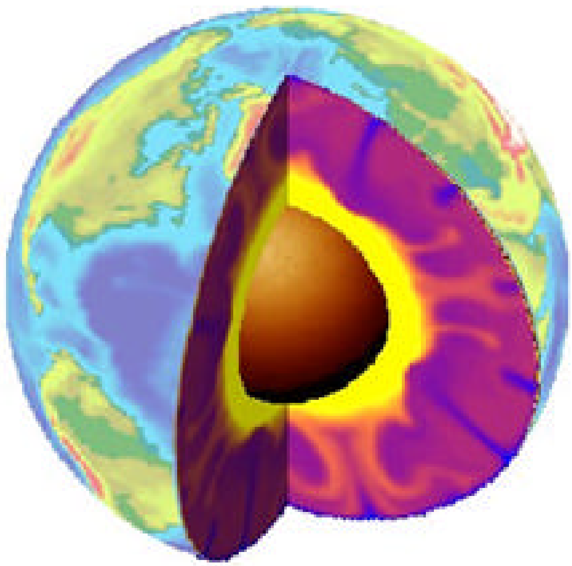
…………. Can we predict future changes?

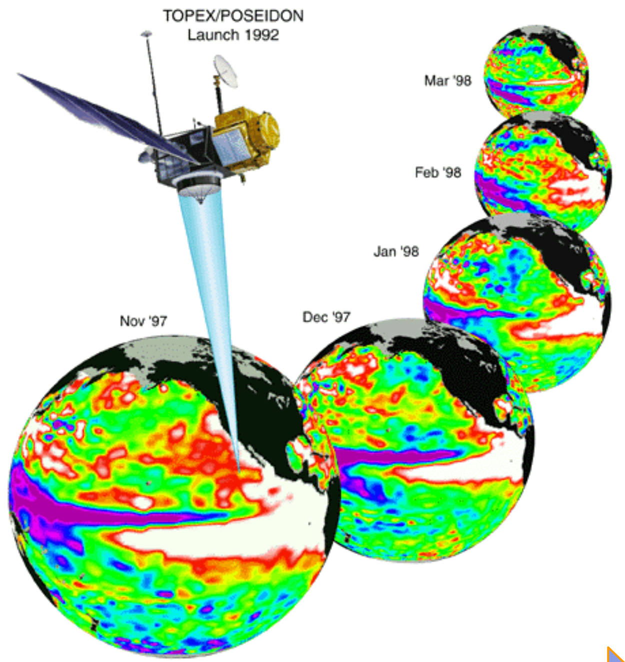


You can download this file from:
http://ese-dropbox.hq.nasa.gov/ese-dropbox/RestlessPlanet.ppt

Solid Earth and Natural Hazards Program ***SENH***

<u>Our Mission:</u> The application of space-borne and air-borne technologies to the study of the structure and dynamics of the Solid Earth and its interaction with the oceans and atmosphere.





Characterization - Understanding - Prediction

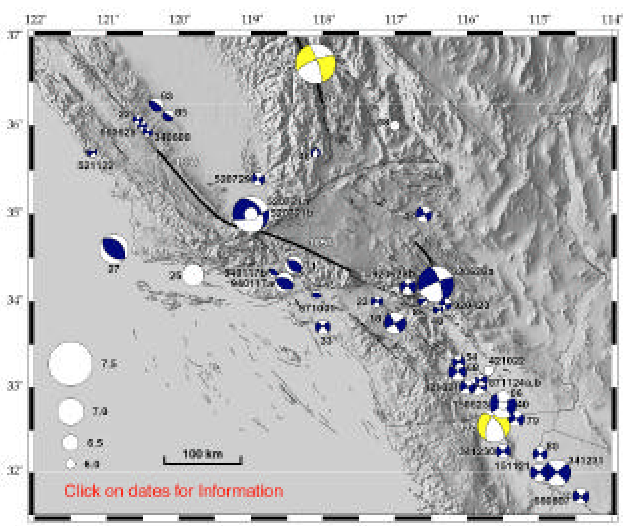
<u>Our Objective:</u> Prediction and management of Natural Hazards for a more secure society.

Not Just an Academic Exercise

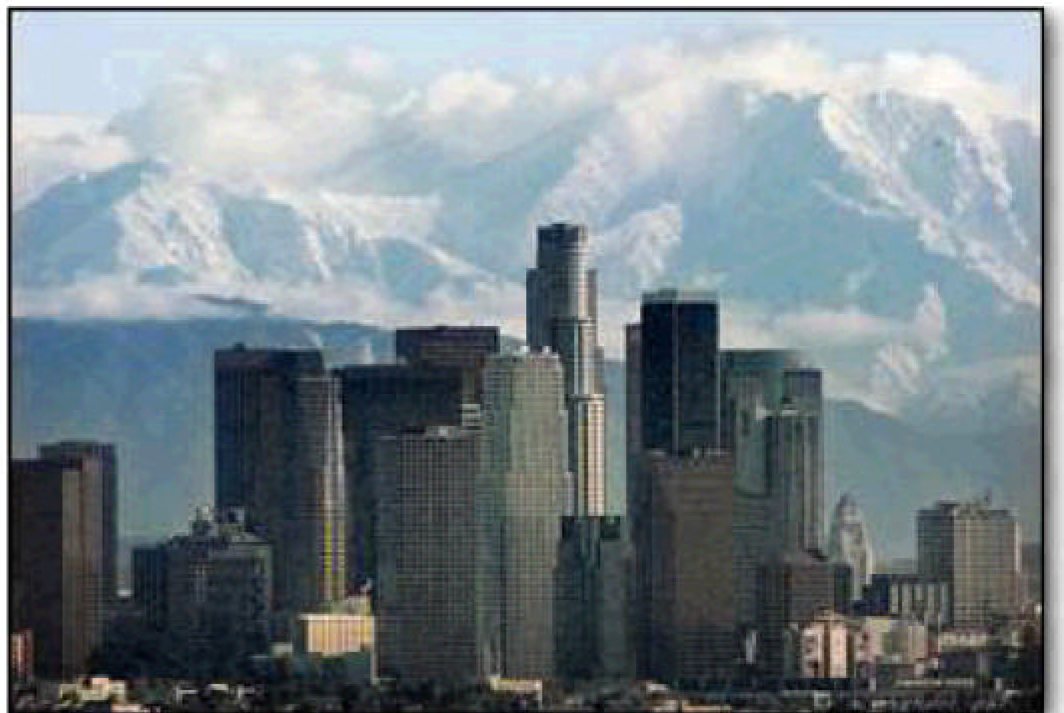
TV News

NBC NIGHTLY NEWS WITH TOM BROKAW

Los Angeles is moving, literally

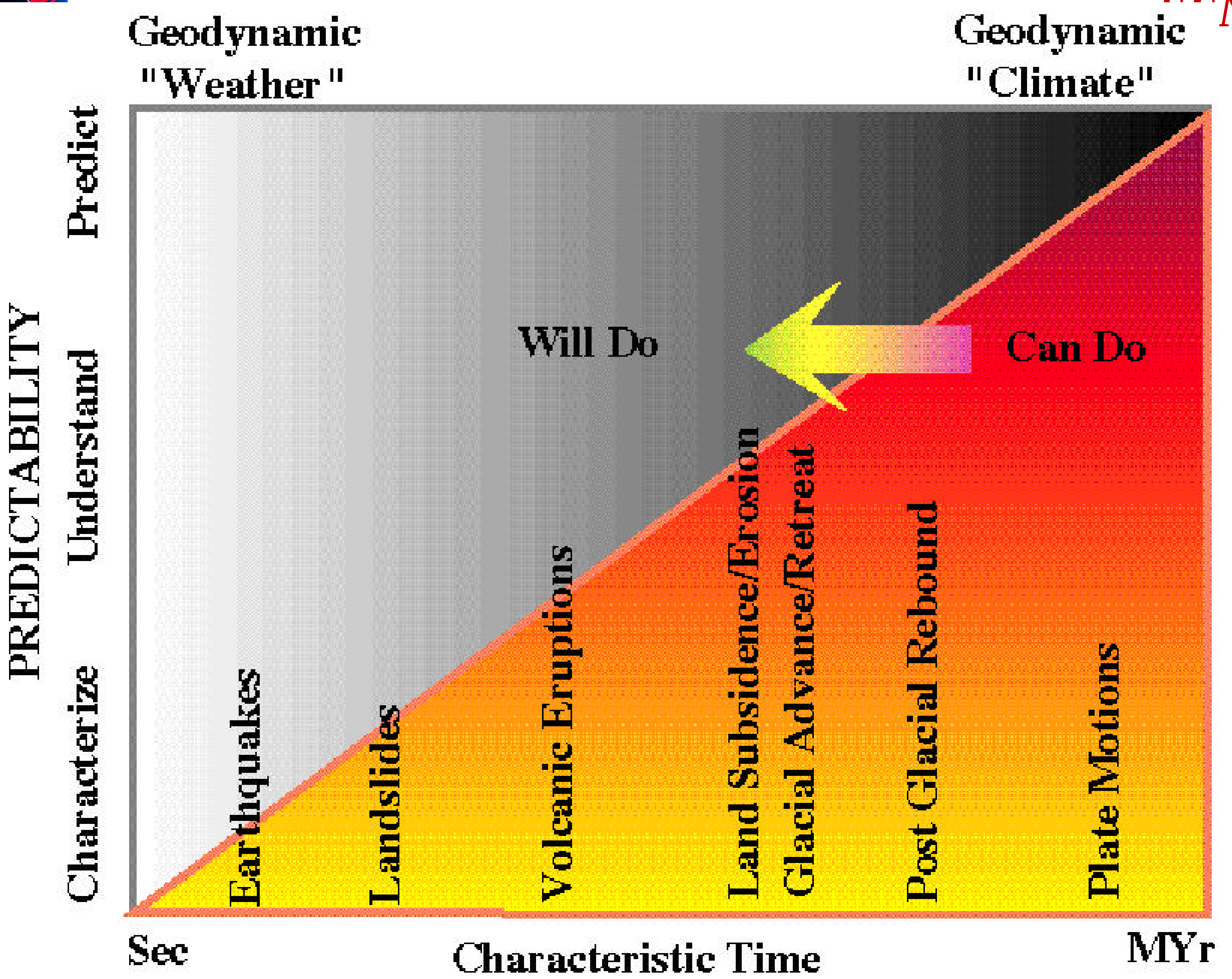


California Earthquakes



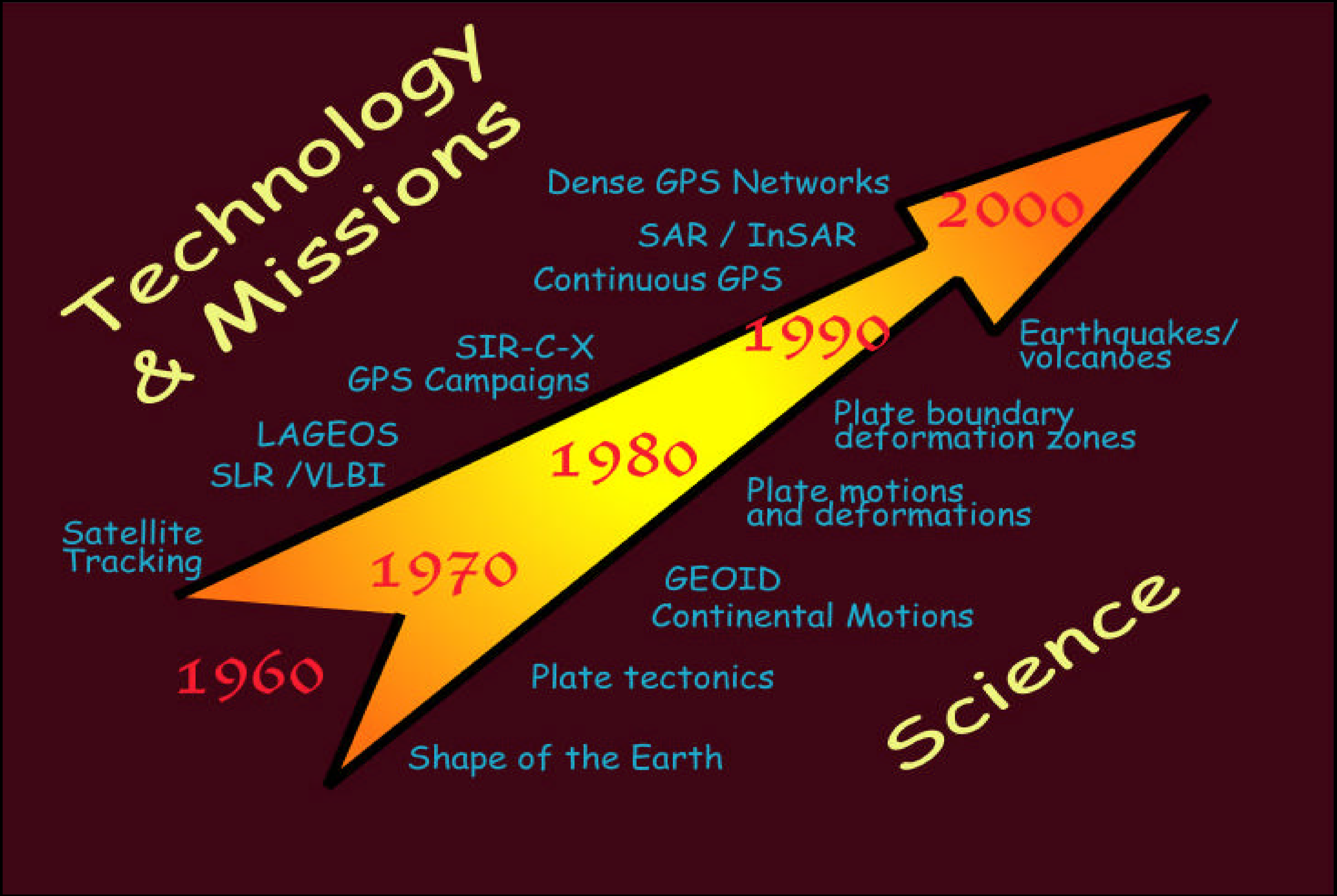
Nick Ut / AP file

LOS ANGELES, August 4 — Scientists at the Jet Propulsion Lab in Pasadena, Calif., have made measurements that suggest that downtown Los Angeles is moving toward the San Gabriel Mountains, and that a new mountain range is being formed beneath Hollywood.


Geodynamic
"Weather"
Geodynamic
"Climate"
PREDICTABILITY
Predict
Understand
Characterize
Will Do
Can Do
Earthquakes
Landslides
Volcanic Eruptions
Land Subsidence/Erosion
Glacial Advance/Retreat
Post Glacial Rebound
Plate Motions
Sec
Characteristic Time
MYr

Infusion of NASA Technology in Solid Earth Science

SENH



A vision of NASA Technology Future Infusions in Solid Earth Science

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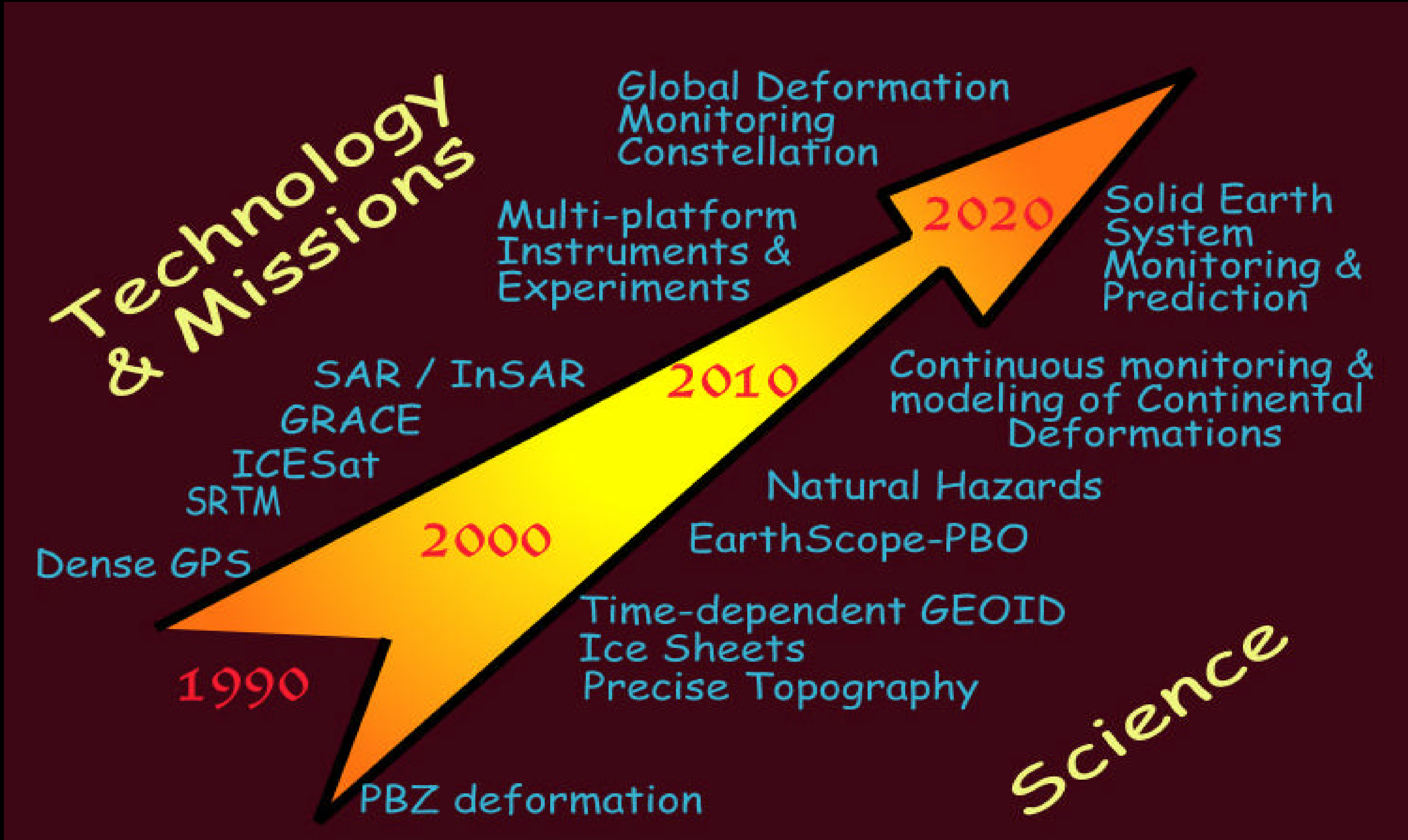

Space Geodetic Technology Maintains the Earth's Reference Frame to millimeter accuracy

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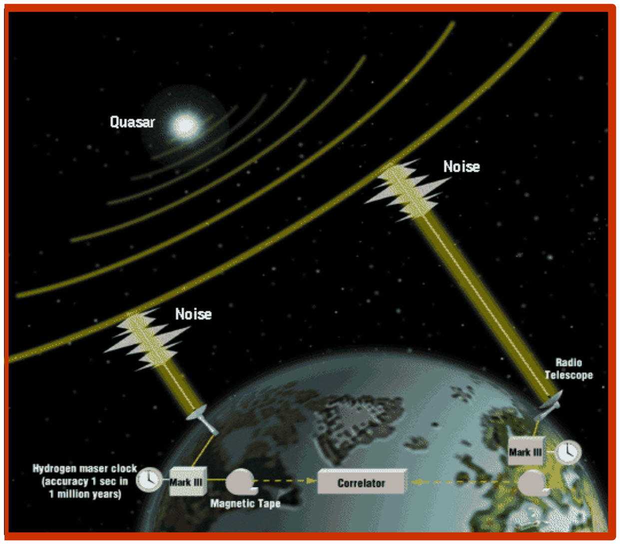
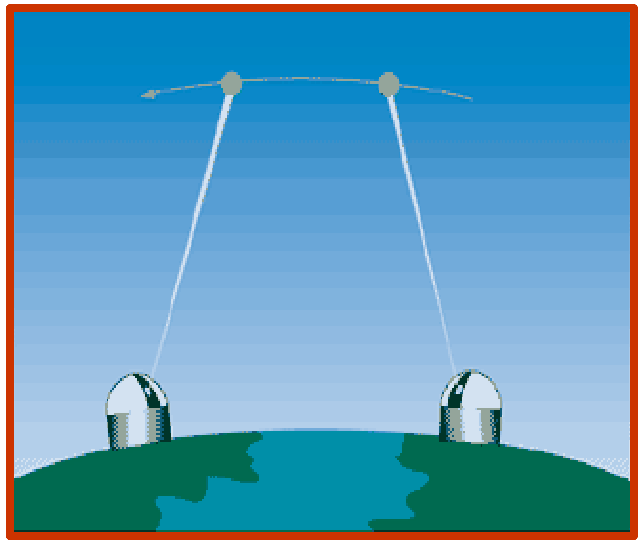
Very Long Baseline Interferometry (VLBI)



- Polar Motion
- Length of Day
- Inertial Reference
- 30 Station Network

Network Organization:
International VLBI Service

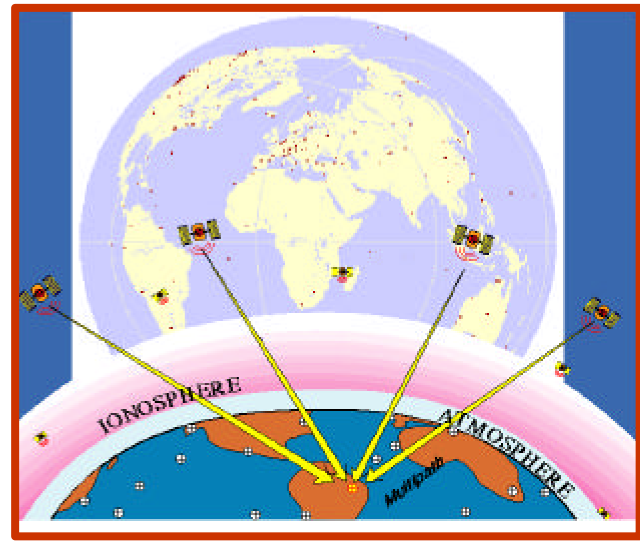
Satellite Laser Ranging (SLR)



- Satellite Positioning < 3 cm
- Time Variable Gravity
- Earth Center of Mass
- 37 Station Network

Network Organization:
International Laser Ranging Service

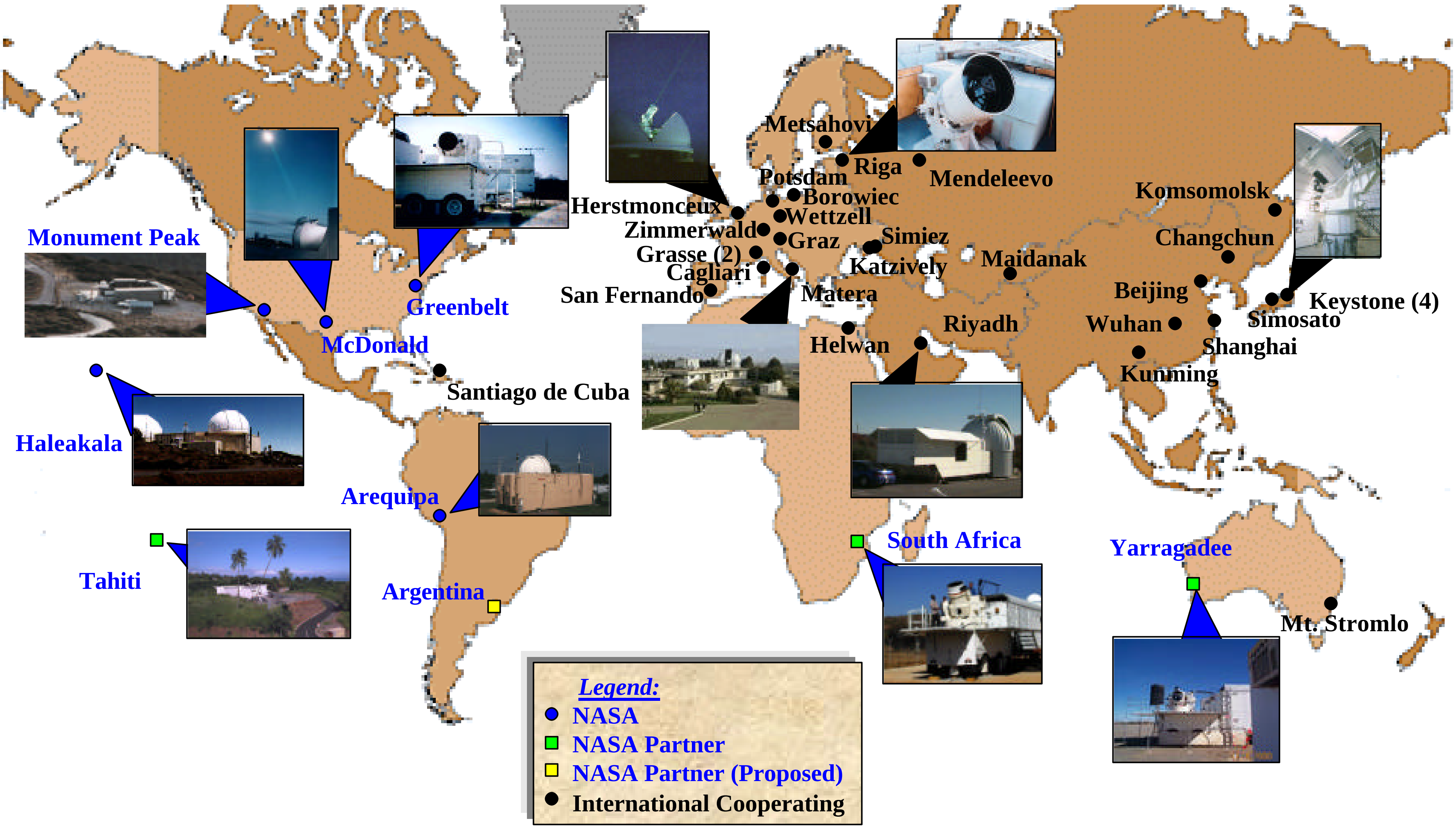
Global Positioning System (GPS)



- Satellite Positioning <10 cm
- Polar motion
- Site velocity
- >250 Station Network

Network Organization:.
International GPS Service

International Satellite Laser Ranging Network



The SLR2000 Prototype

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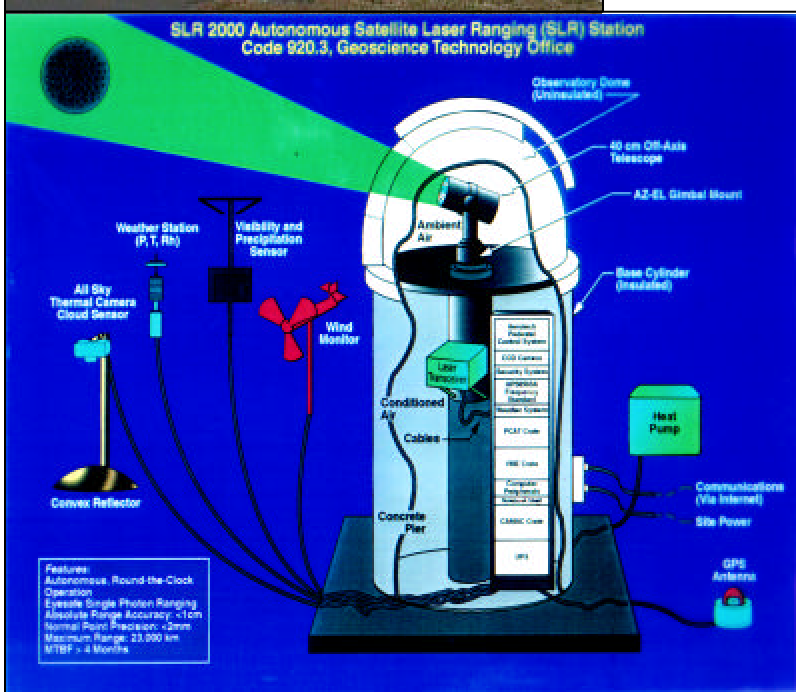
An Optical Com Ground Network?



System Characteristics

- **Fully automated, no operators**
- **Subcentimeter ranging accuracy**
- **Tracks satellites to 20,000 km altitude**
- **Tracks 24 hours/day, 7 days/week**
- **No ocular, chemical, or electrical hazards**
- **Automated satellite scheduling**
- **Improved global distribution**
- **Hourly data processing and delivery via Internet (modem backup)**
- **Replaces manned MOBLAS, TLRS systems**
- **Self-monitoring, low maintenance**
- **Reduced replication and operating costs**
- **Use simpler technologies for increased reliability**
- **Relatively small and compact**
- **12 station global network is planned**

IGDG, NASA Software of the Year 2000, is applied to A State-Space Global Differential GPS System

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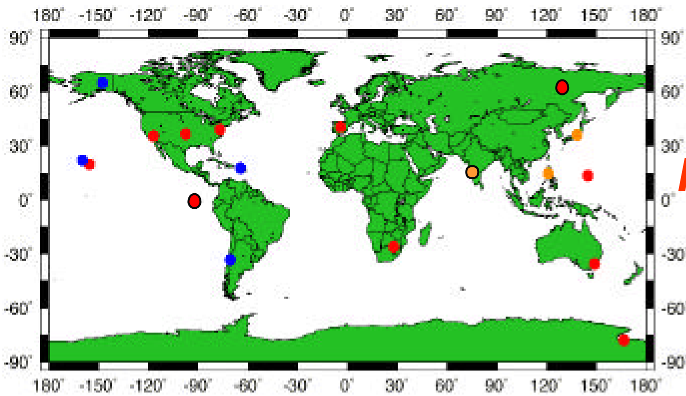
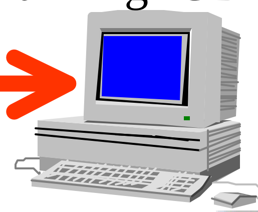


Internet

Processing center running IGDG



Internet

Broadcast

Remote user

Revolutionary new capability:

decimeter real time positioning, anywhere, anytime

Capability		JPL's IGDG	Un-augmented GPS	Others (WADGPS services)
Coverage:	Global	Yes	Yes	No
	Seamless	Yes	Yes	No
	Usable in space	Yes	Yes	No
Accuracy:	Kinematic applications	0.1 m horizontal 0.2 m vertical	5 m	> 1 m
	Orbit determination	0.01 – 0.05 m (goal)	1 m	N/A
Dissemination method		Internet/broadcast	Broadcast	Broadcast
Targeted users		Dual-frequency	Dual-frequency	Single-freq.

See also: Muellerschoen et al., GPSWorld, January, 2001

For more info look up
http://gipsy.jpl.nasa.gov/igdg

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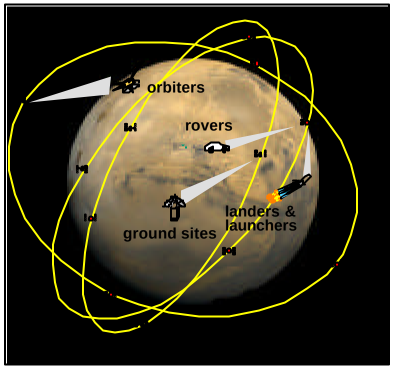
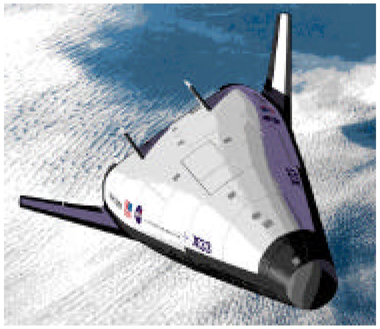
Science and Technology Impact

NASA impact:

- **Enables autonomous operations in Earth orbit**
    - **- Save $M/year/mission on ground operations (e.g. Topex)**
    - **- Enables timely monitoring and response to natural hazards (e.g., SAR)**
    - **- Enables intelligent, cooperating sensor webs in Earth orbit**
- **Enables real time analysis of ground GPS data**
    - **- For operational weather forecasting (e.g., Champ, COSMIC)**
    - **- For crustal motion (Earthquakes, volcano eruptions)**
- **Support AirSAR, X33/RLV**
- **Prototype for Mars Network**



X33/RLV carries IGDG
For real time positioning

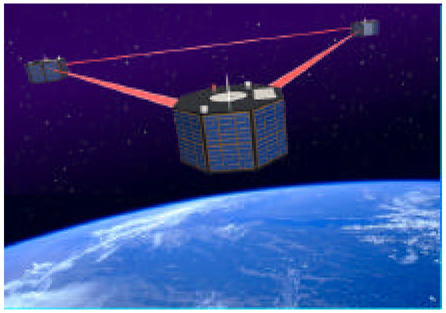


Commercial impact:

- Enable precision farming, construction, oil operations, surveying, …

- Enhance transportation safety and efficiency

- Promote GPS system development



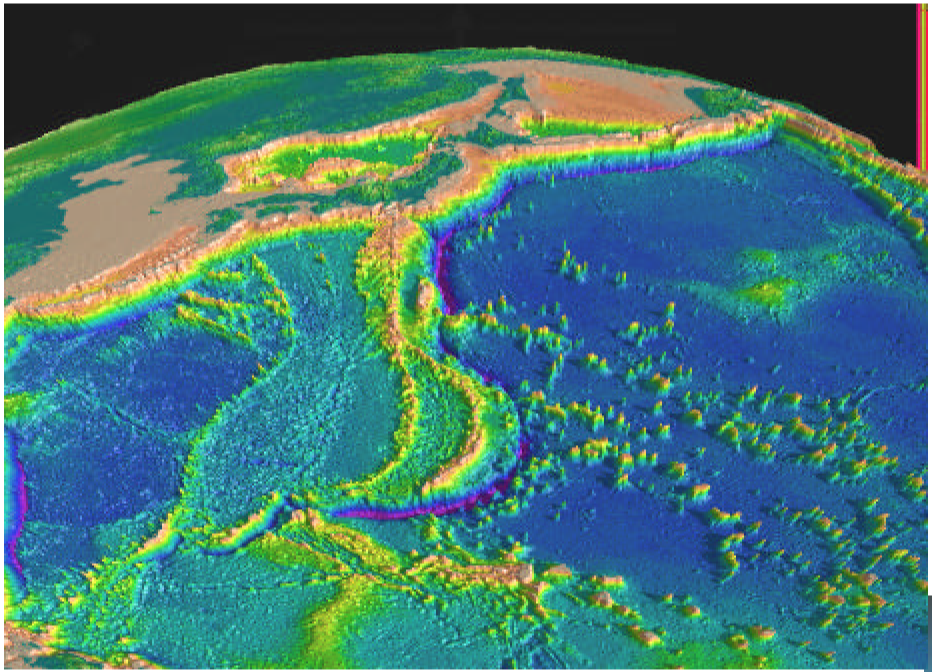
Military Applications:

- Enhance GPS system operations

- Ultra precise guidance anywhere, anytime (no local infrastructure needed)

- Precise geolocation (no local infrastructure needed)

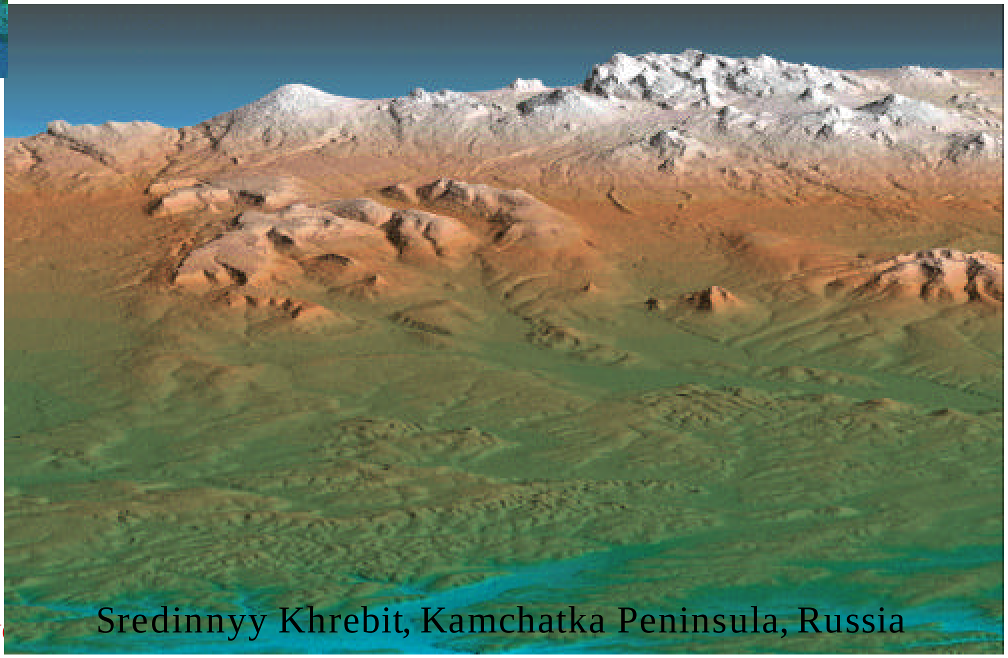
Accurate High Resolution Topography is a Priority *SENH*



In 1983 scientists from Columbia University produced the first satellite altimetry derived Gravity Field

NASA's SEASAT gave us the first complete estimate of ocean bathymetry -over 70% of the Earth's surface

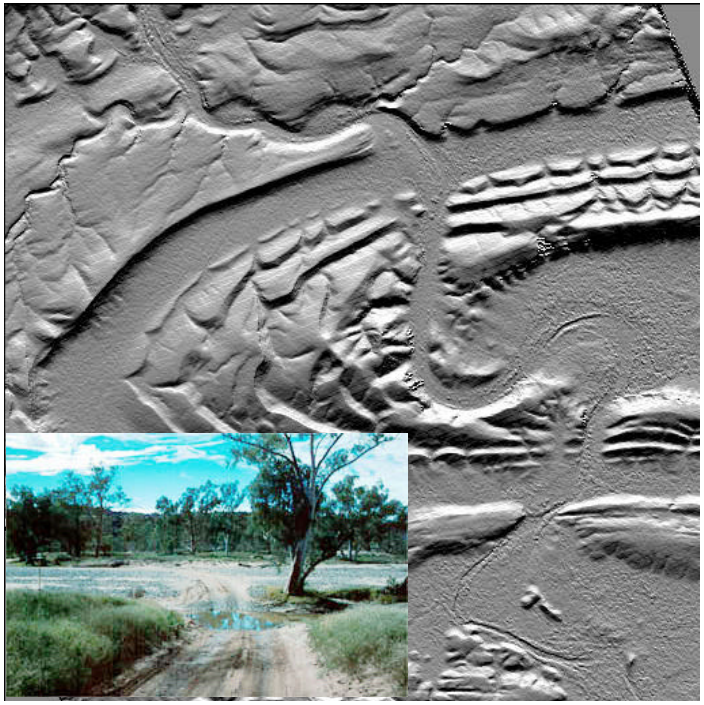
In 2000 the JPL Shuttle Radar Topography Mission provided the first uniform mapping of the Earth's land surface with decameter accuracy.



Sredinnyy Khrebit, Kamchatka Peninsula, Russia

…..But we need centimeter scale accuracy in topography *SENH*

Such as: floodplain modeling based on data fusion of polarimetric SAR interferometry and laser altimetry.



Provide input fields of topography as well as the state of soil moisture and vegetation cover for a hydrological model to enable more accurate prediction of flooding events and flood extent in riverine and coastal floodplains.

Importance:

- Will provide a scientific basis for flood prediction in floodplains and coastal lowlands
- Will develop state of the art remote sensing techniques and inversion algorithms to provide input fields required by a physically based hydrologic model

Anticipated benefit:

- Operational monitoring of input fields, coupled with the predictive capabilities of the hydrologic model, will allow disaster agencies to predict the occurrence and extent of flooding, thereby saving lives and property

We Also Need Continuous Global Measurements of Surface Change

SENH

Strain is continuously accumulating

- Need long-term measurements to enable a new class of models that capture non-linear behavior at a range of spatial and temporal scales

Strain events are spatially and temporally distributed

- Need a statistically robust set of event cycles to construct and validate physical models
  - Co-/post-seismic deformation from all non-oceanic earthquakes with Magnitude > 5 and Depth < 30km
  - All active volcanoes (not necessarily erupting)
  - Glacier/ice sheet flow, including surges and ice streams
  - Vector measurements, mm-accurate, dense in time and space

GPS networks measure crustal defomation in four dimensions

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QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

QuickTime™ and a
GIF decompressor
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GPS Provides Time Continuous Deformation Measurement while Interferometric Synthetic Aperture Radar Provides Spatially Continuous Measurements.

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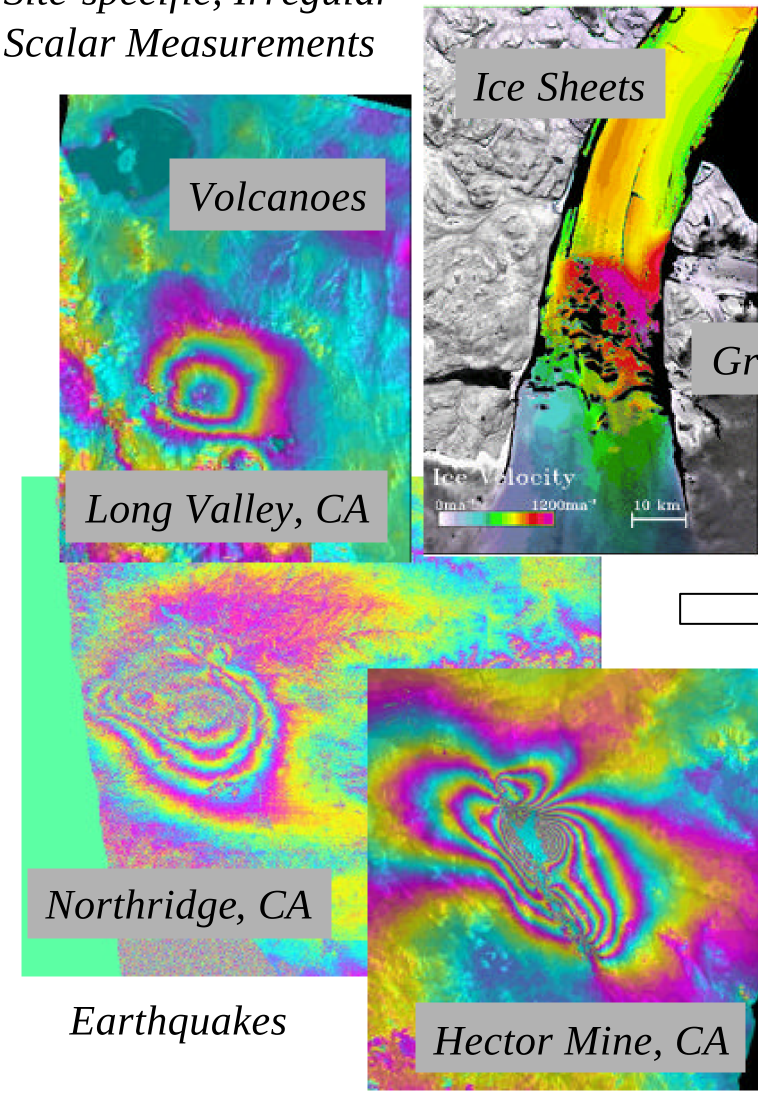
We can now observe the entire Earthquake Cycle.

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

QuickTime™ and a
GIF decompressor
are needed to see this picture.

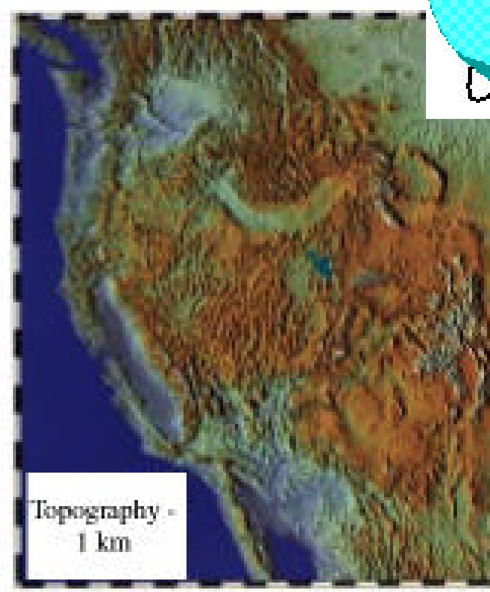
Interferometric SAR Observations: *SENH*
Present and Future

Site-specific, Irregular Scalar Measurements



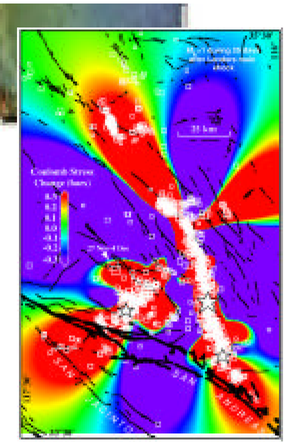
Earthquakes

Operational Constellations for Plate Boundary Scale Vector Measurements



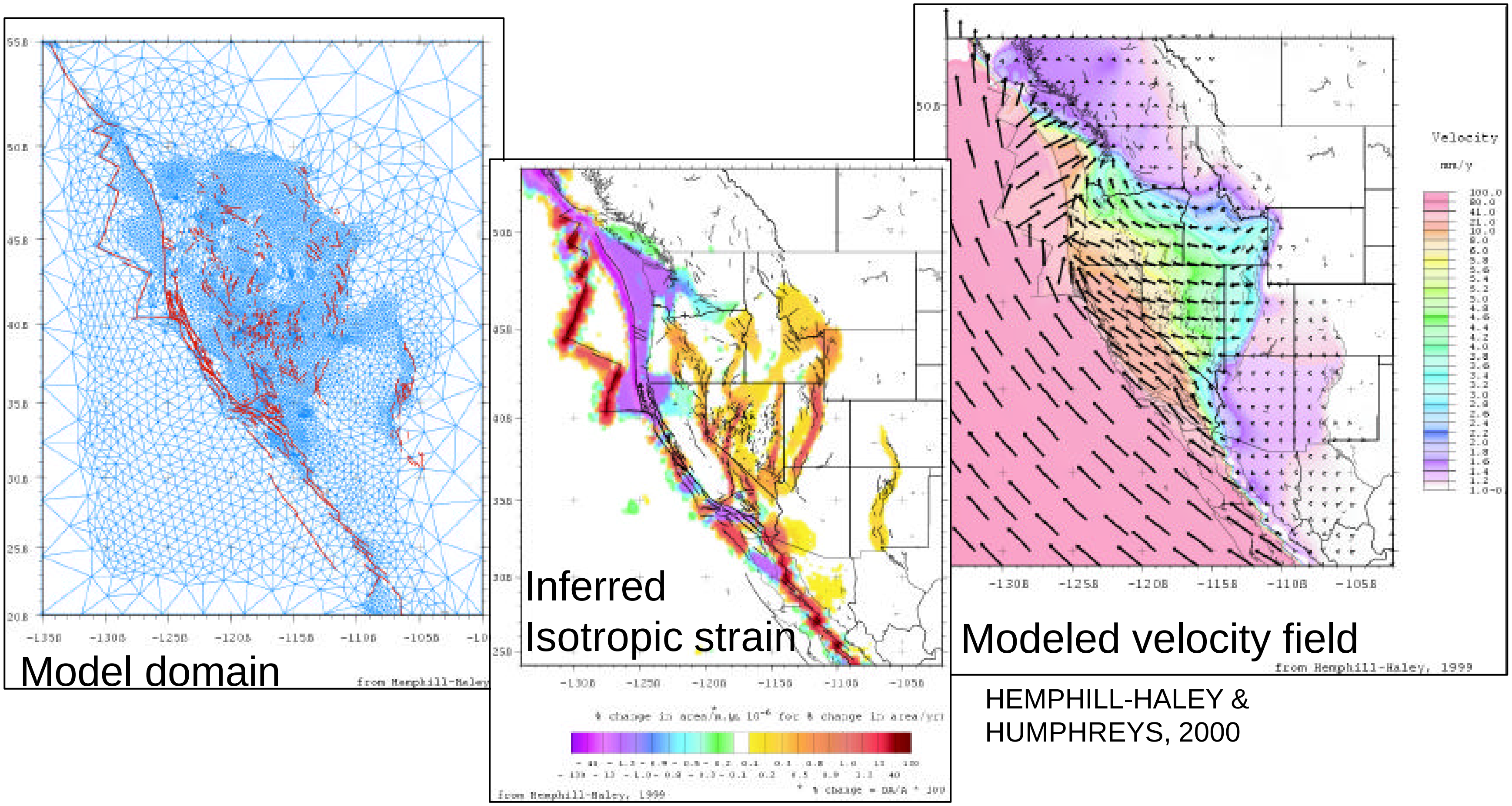
PBO

Stress Change



Wide bandwidth communications and Multi-scale Geodynamic Modeling are a critical components in effective Solid Earth Applications

SENH



HEMPHILL-HALEY &
HUMPHREYS, 2000

Measurements → Models → Prediction

Technology Options in Geodetic Imaging and Space-borne Seismology

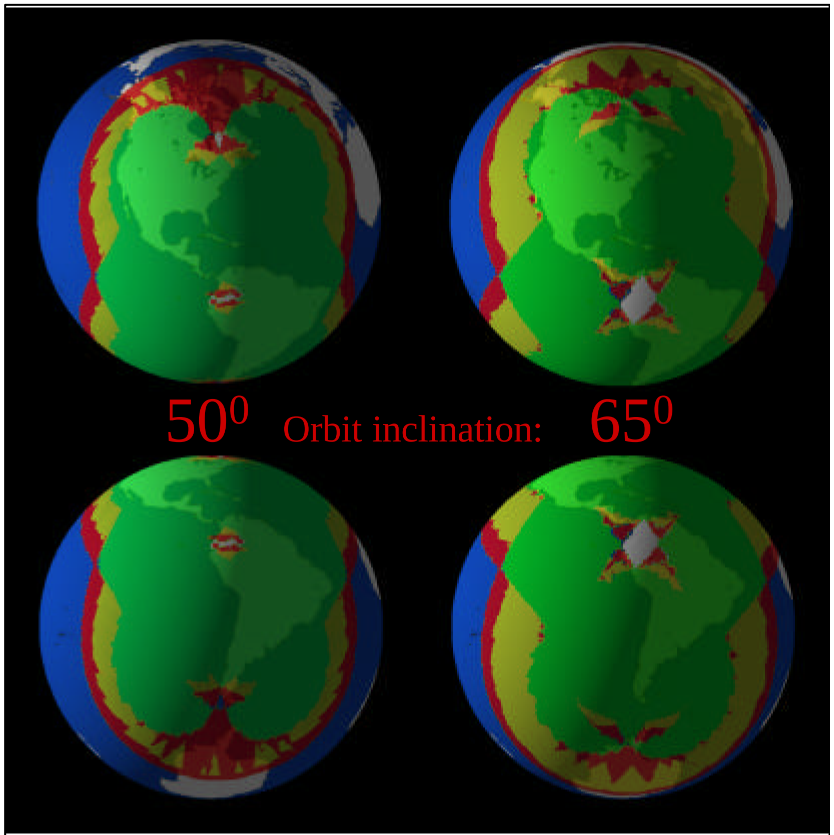
SENH

Sensor Options:

- INSAR from Geosynchronous Orbit
- LEO/MEO INSAR/LIDAR constellations
- Airborne Interferometric SAR
- Ionospheric Tomography
- High resolution ocean topography swath mapper

Supporting Technologies:

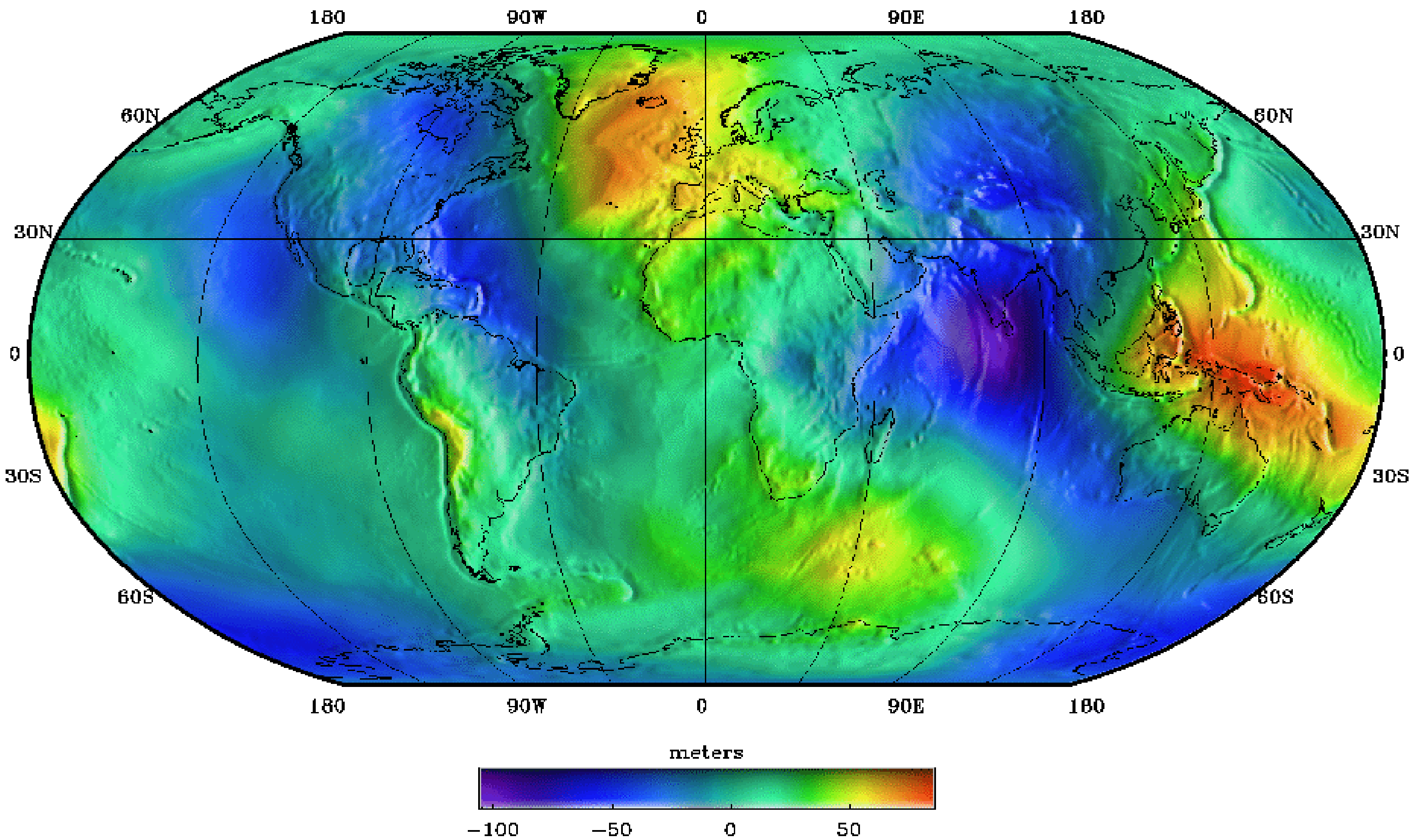
- High Bandwidth Communications (Direct Broadcast?)
- Large Aperture Antennas
- Advanced Lidar Systems
- Precision Navigation for Spaceborne and Airborne platforms
- On Board Processing
- Advanced Modeling Systems



Coverage from a geosynchronous INSAR aperture=700 m^2 at 50° orbit inclination on the left, 65° inclination on the right. Green indicates 3-d mapping, yellow 2-d and red 1-d daily measurement of deformation vector >1.5 cm 3-D rms. (Madsen et al., 2000)

Non-Photonic Subsurface Measurements: Long Term Measurements of the Geoid

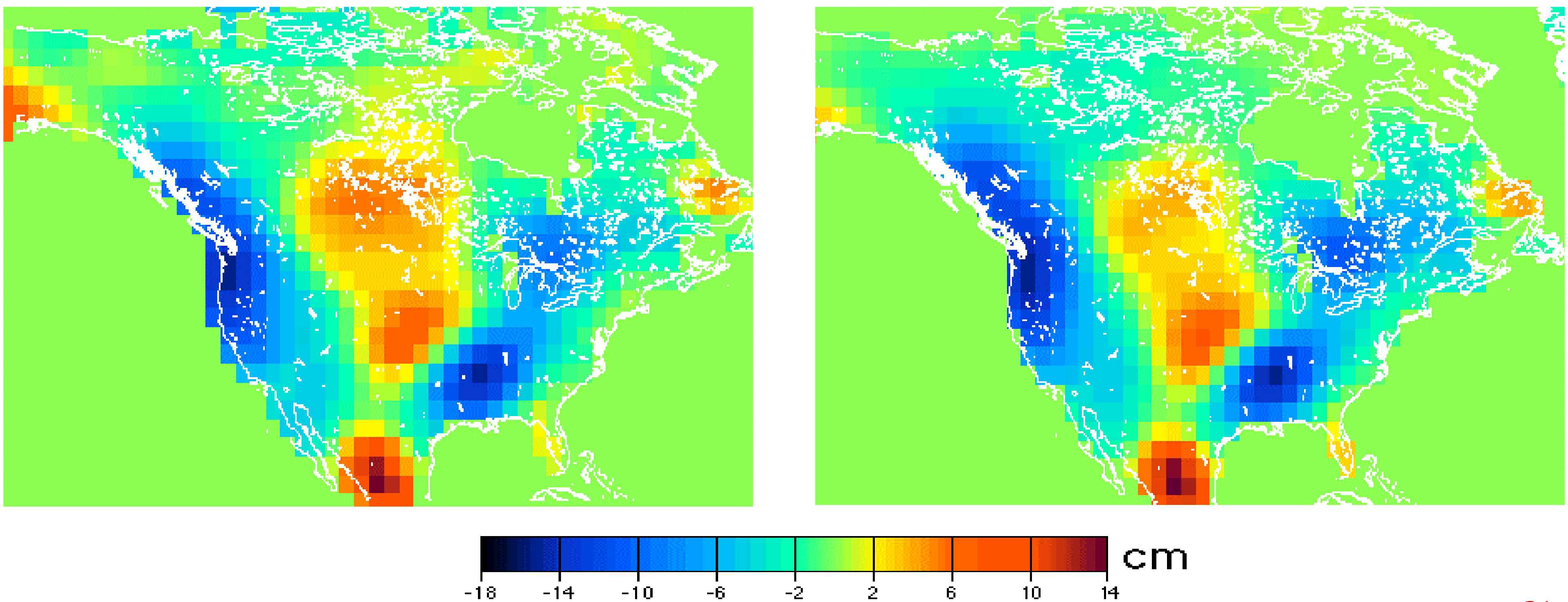
SENH



EGM96
GSFC/NIMA

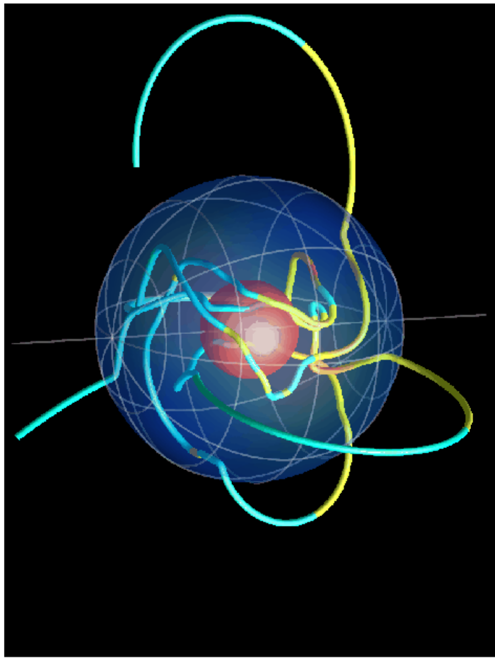
SENH

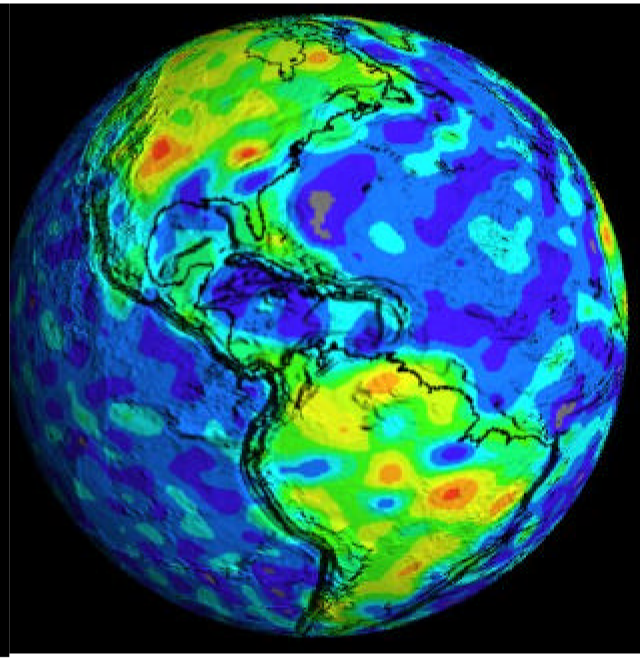
GRACE will measure the time variation in gravity to estimate mass transport. Diagrams below display annual moisture accumulation and the simulated GRACE recovery including system noise. We should also be able to measure the steric effect in Oceanic volume.

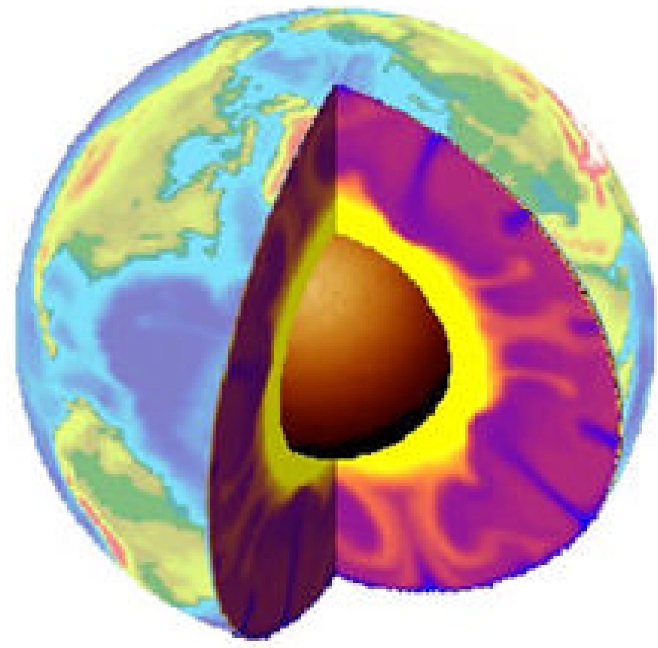


Non-Photonic Subsurface Measurements: Long Term Geomagnetic Field Measurements

SENH







MHD Core Circulation **Lithosphere Sources** **Magnetotelluric Imaging**

- Information on the structure and evolution of the Earth's crust
- Baseline for linking independent surface surveys
- Thermal state and petrology of the lithosphere
- Time varying components may yield information on crustal stress changes, conductivity changes
- Component of decadal scale mass transport and momentum change

Technology Requirements for Geopotential Field Measurements

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Synoptic Global High Resolution Geomagnetic Field Measurement:

- Low mass and power, zero drift high accuracy vector sensor
- Attitude knowledge ~arcsec or better
- Position knowledge ~ centimeter
- Tethered or formation fliers
- Autonomous nanno-satellite constellations

High Sensitivity Time Varying Gravity Field Measurement:

- Tensor or range rate (better than µm/sec optical interferometer) sensors
- Low power long life thrusters
- Formation flying technology
- High sensitivity accelerometers $<10^{-10}$ g
- Precise positioning ~mm
- Surface air pressure better than 1 mbar